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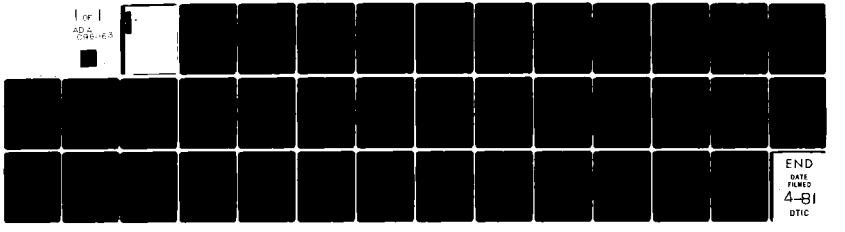

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COMPUTER MANAGED INSTRUCTION IN THE NAVY: II. A COMPARISON OF TWO STUDENT/INSTRUCTOR RATIOS IN CMI LEARNING CENTERS

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Students at the Basicc Electricity and Electronics School, San Diego were assigned to learning centers (LCs) with either an 18:1 or 30:1 student/instructor (S/I) ratio to determine the effects on student and instructor behavior in an individualized computer-managed instruction (CMI) course. Results of data analyses revealed that the 30:1 S/I ratio resulted in longer training time for students in certain career patterns than did the 18:1 S/I ratio. The S/I ratio had no consistent differential effect on: first-try scores on module or phase tests, number of remediations per module, number of unsatisfactory

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performance tests, or student attrition from the course. Instructors in the 30:1 S/I ratio spent less time per question answering student technical questions and more time on administrative duties than did instructors in the 18:1 condition.

It was recommended that CMI courses should be developed or revised to allow the computer to perform the maximum amount of administrative functions to reduce the CMI instructor workload. In any future efforts to assess the effects of S/I ratio changes, technical schools should consider performance data for students and instructors, and relate it to variables such as course content, testing strategies, and LC operating procedures.

FOREWORD

This work was performed under Work Unit Z1176-PN.01 (Improving the Navy's Computer-Managed Training System) as part of an R&D project aimed at improving the Navy's operational computer-managed instruction (CMI) system. It was sponsored by the Deputy Chief of Naval Operations (OP-01).

This report is the second in a series of five on Navy CMI. The first, NPRDC SR 80-33, described the problem areas that limit the effectiveness of the CMI system and the R&D plans that have been developed to address these problem areas. This report describes the effects of two student/instructor (S/I) ratios (18:1 and 30:1) on student performance and instructor behavior. Results of the CMI research will be used by the Chief of Naval Education and Training (CNET), the Chief of Naval Technical Training (CNTT), commanding officers of all the Navy CMI schools, and others concerned with computer-based instruction.

Appreciation is expressed to the personnel in the Service School Command, San Diego, especially to the instructors in the Basic Electricity and Electronics School, for their efforts with this work. Appreciation is also extended to Mr. Ernest Owens, CNTT (Code N312), who was instrumental in facilitating the conduct of the work and to Ms. Linda Graham, now associated with CNTT, for her assistance in developing the instructor behavior scoring procedures and data collection.

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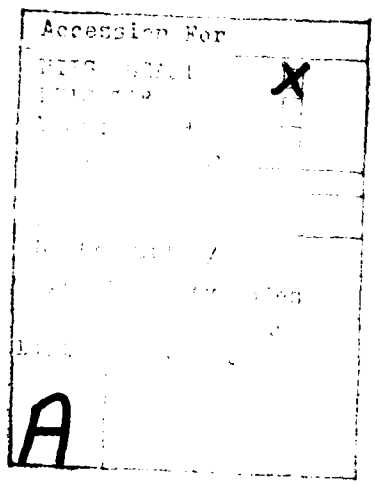

SUMMARY

Problem

The student/instructor (S/I) ratio of 18:1 in many Navy computer-managed instruction (CMI) learning centers (LCs) may not be optimal in terms of instructor utilization and student needs. If the LCs could be operated at higher S/I ratios without lowering student achievement and instructor performance, training costs could be reduced.

Objective

The objective of this work was to compare the effects of 30:1 and 18:1 S/I ratios on student achievement and instructor performance.

Approach

Students at the Basic Electricity and Electronics (BE&E) School, San Diego, going through Computer Coursefile 69, were randomly assigned to an LC maintained at an S/I ratio of either 18:1 or 30:1. Data were collected on: (1) attrition, (2) training contact hours, (3) first-try scores on module tests and phase tests, (4) number of remediations per instructional module, and (5) number of unsatisfactory scores on practical tests. Observational data were also collected on the frequency and duration of categories of instructor behaviors during the 6-hour CMI instruction shift.

Findings

1. *The 30:1 S/I ratio resulted in longer training time* for students in certain career patterns than did the 18:1 S/I ratio.

2. The S/I ratio had no consistent differential effect on first-try scores on module tests or phase tests, number of remediations per module, or number of unsatisfactory performance tests. Further, there were no significant differences in student attrition.

3. Instructors in the 30:1 S/I ratio condition tended to spend more time in duties involving testing and student administrative activities than did instructors in the 18:1 S/I ratio condition. Although this difference was not statistically significant, it is consistent with the finding that instructors in the 30:1 S/I ratio condition spent less time per question answering student technical questions, since they were responsible for more students than were the instructors in the 18:1 condition.

Conclusions

The larger S/I ratio (30:1) appears to have some detrimental effects on both student training time and instructor behavior for BE&E Computer Coursefile 69. However, the course management strategy for BE&E has been changed since the initial results of the effort were reported to the sponsor. BE&E now uses Coursefile 71, which eliminates many of the manual administrative requirements of Coursefile 69. Alteration of a CMI course management strategy to eliminate manually performed administrative activities for both students and instructors may allow the LCs to be operated using higher S/I ratios without adverse effects on performance.

Recommendations

1. When revising or developing CMI courses, technical training program coordinators and CMI course designers should alter CMI course management strategies to allow the computer to perform those administrative functions currently performed by instructors or students.

2. Technical training schools should record performance data for both students and instructors during future efforts to increase S/I ratios on an operational basis. These performance data must be related to other variables (e.g., LC operating procedures, course content, and knowledge and performance testing strategies) to determine the overall effects of S/I ratio changes.

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INTRODUCTION

Problem and Background

The Navy has attempted to meet the problem of rising technical training costs through the development of the computer-managed instruction (CMI) system. This system manages self-paced, individualized instruction conducted at technical training schools across the continental United States through a centralized computer located at the Management Information and Instructional Systems Activity (MIISA), Millington, TN. Although this innovation in large-scale training has resulted in considerable reductions in training time, further modifications are desirable to achieve more cost-effective training. Therefore, the Navy Personnel Research and Development Center (NAVPERSRANDCEN), San Diego, has established a comprehensive research and development (R&D) effort directed at making the CMI system an even more efficient component of Navy technical training. The initial report on this research effort (Van Matre, 1980) described the problem areas that limit the effectiveness of the CMI system and the R&D plans that have been developed to address these problem areas. During the problem analysis, alternate student to instructor (S/I) ratios were compared in a CMI learning center (LC) at the Basic Electronics and Electricity (BE/E) School in San Diego to determine whether student performance would suffer if the S/I ratio were increased. Although an increase in the S/I ratio did not result in performance decrements, training time did increase in some career paths. The Navy has lost a significant number of instructor billets because of funding limitations. The effects of this loss could be mitigated if the LCs could operate with a higher S/I ratio without lowering the quality of instruction.

Few researchers have directly addressed the problem of optimal S/I ratios. Smith and McCluskey (1975), in a review of 267 studies of effects of class size in lectures at the elementary and secondary school levels, found that only 22 of the studies met general standards of good experimental methodology. Of these, results of 16 indicated that small classes fared better than large ones in terms of (1) student performance, (2) teacher or administrative opinion, (3) teacher's knowledge of students, and (4) classroom practices. In general, those studies that assessed the effects of class size on variables other than student achievement found that smaller classes were better, while those that assessed student performance only were divided in their findings. None of the studies examined class size or S/I ratios in individualized or computer-managed courses.

Studies of class size effect have also ignored two other areas most relevant to Navy CMI; namely, manual performance skills and technical knowledge training. Although Haskell (1964) did examine the effect of class size on the technical training provided to high school geometrical drawing students, he found no differences between the performance of students in small classes (up to 17 students) and those in larger ones (from 17 to 34 students). Likewise, Hopper and Keller (1966) found that class size (28 versus 56 students) did not effect results when teaching writing skills to college students. Bolander (1973), however, found that college students in small classes (8 to 12 students) were more motivated than those in large classes (18 to 49).

In evaluating the relevance of these findings to the question of optimal S/I ratios in computer-managed Navy technical training, it must be noted that class size as a variable is not equivalent to S/I ratio, because support personnel are often present in public school classrooms. Also, the class-size studies did not control for teaching method, record teacher behaviors, consider cost effectiveness, or examine effects in individualized or computer-managed instruction systems.

Certain aspects of computer-based instruction and the instructor role within the Navy CMI system make generalizations from previous research findings even more

hazardous. Class size as a variable may, in fact, simply be a compilation of other variables concerning teacher behaviors and instructional methods. Such variables as time spent in lecturing, generating class discussion, and providing feedback would be affected by changes in class size in traditional public school classrooms, and may in fact be responsible for the findings obtained. Since these variables are not operative within a CMI system, however, relationships between student performance and class size in a CMI system might be expected to differ from those found in more traditional lecture settings.

Objective

The objective of this effort was to determine how changing the S/I ratio from 18:1 to 30:1 would affect student achievement and instructor behavior. It was conducted at the BE/E School, San Diego.

APPROACH

Method

Four CMI LCs were dedicated for this study. Two operated during the AM shift (0600 to 1200); and two, during the PM shift (1200 to 1800). During each shift, one LC was maintained at an 18:1 S/I ratio; and the other, at a 30:1 S/I ratio. These ratios were maintained throughout the study by randomly assigning entering BE&E students as vacancies occurred in either LC. During the first week, the LCs were loaded with students at the rate of approximately six per day, with each student receiving the normal indoctrination to BE&E Coursefile 69. This gradual random assignment of students to the LCs tended to minimize the number of students working on the same instructional module at any one time. The LCs were operated at their respective S/I ratios for approximately 4 months, so that all study participants would have an opportunity to complete the BE&E course.

During the instructional day, students proceeded through the BE&E Coursefile 69 materials, moving among the LC, the experiment laboratory, and the performance testing (PT) laboratory, as various course requirements were satisfied. Academic or discipline problems were dealt with under normal BE&E school policy. Students and instructors spent 6 hours in the CMI environment with BE&E training and 2 hours with other Navy training requirements during each 8-hour training day.

Subjects

A total of 237 students participated, 78 in the 18:1 S/I condition and 159 in the 30:1 condition. Table 1 shows the numbers of students, graduates, and nongraduates in each condition by job rating and module completion pattern. (Subsequent tables present data only for graduating students for whom complete data were available.) The module completion pattern was included because students in the different ratings complete different groups of BE/E modules. Module completion pattern 2 differs from the others, in that some of the students in the Electronics Technician (Communications) (ETN), Electronics Technician (Radar) (ETR), Interior Communications Electrician (IC), and Communications Technician (Maintenance) (CTM) ratings complete all of the 25 required modules at BE/E San Diego (regular pattern), while others complete the first 14 modules at other BE/E schools and then are transferred to BE/E San Diego, where they complete modules 15 through 25 (splice pattern).

Table 1

Sample Sizes by Module Completion Pattern, Computer Data Processing (CDP) Code, and Student/Instructor (S/I) Ratio

Module Completion Pattern	CDP Code	Rating	S/I Ratio 18:1 Grad N	18:1 Non-grad N	18:1 Total N	30:1 Grad N	30:1 Non-grad N	30:1 Total N	Total
1 (Modules 1-14)	6276	STG	5	0	5	12	0	12	17
	6277	STS	4	0	4	15	0	15	19
Subtotal			9	0	9	27	0	27	36
2 (Modules 1-25)[a]	6269	DS	2	0	2	6	0	6	8
	6271	ETN:							
		Regular	8	0	8	9	1	10	18
		Splice	7	0	7	5	0	5	12
	6272	ETR:							
		Regular	0	2	2	5	0	5	7
		Splice	2	0	2	6	0	6	8
	6274	IC:							
		Regular	4	0	4	12	5	17	21
		Splice	0	0	0	2	0	2	2
	6275	EW	1	1	2	2	0	2	4
	6352	RM	1	0	1	0	0	0	1
	6358	FTM	4	2	6	11	1	12	18
	6359	FTG	2	0	2	7	0	7	9
	6360	CTM:							
		Regular	0	0	0	2	1	3	3
		Splice	1	0	1	0	0	0	1
Subtotal			32	5	37	67	8	75	112
(Regular)			(22)	(5)	(27)	(54)	(8)	(62)	(89)
(Splice)			(10)	(0)	(10)	(13)	(0)	(13)	(23)
3 (Modules 1-12, 15, 21, 23, & 25)	6373	EM	15	6	21	28	8	36	57
4 (Modules 1-12)	6361	GMT	1	1	2	3	0	3	5
	6362	GMG	5	1	6	7	9	16	22
	6363	GMM	0	1	1	1	0	1	2
	6270	CE	0	2	2	0	0	0	2
	6167	Unknown	0	0	0	0	1	1	1
Subtotal			6	5	11	11	10	21	32
Grand Total			62	16	78	133	26	159	237

[a]In the regular pattern for ETNs, ETRs, ICs, and CTMs, all 25 modules are taken at BE/E, San Diego; in the splice pattern, only modules 15-25 are taken at San Diego.

A complication arising from the student data is that different ratings require different minimum Armed Services Vocational Aptitude Battery (ASVAB) qualifying scores for school admission, resulting in different student aptitude levels. This qualifying score, consisting of the sum of various ASVAB subtest scores, is computed differently for individual ratings, making direct comparisons of aptitude levels across ratings difficult. The two qualifying equations used for ratings at the time of this study are:

1. Mathematics Knowledge (MK) + Electrical Information (ET) + General Science (GS) + Arithmetic Reasoning (AR). This equation is used for Sonar Technician--Surface and Submarine (STG and STS), Data Systems Technician (DS), Electronics Technician (ETN and ETR), and Fire Control Technician--Gun Fire Control and Surface Missile Fire Control (FTG and FTM), Electronic Warfare (EW), Radioman (RM), and Communication Technician Maintenance (CTM) ratings.

2. Word Knowledge (WK) + Mechanical Comprehension (MC) + Shop Information (SI)/ This equation is used for Interior Communications Electrician (IC), Electrician's Mate (EM), and Gunner's Mate--Guns, Missiles, and Technician (GMG) (GMM), and GMT), and Construction Electrician (CE) ratings.

Because differences in aptitude levels may result in differences in student performance, T-tests were used to compare mean ASVAB qualifying scores for each rating across the S/I ratios. Results revealed no significant difference between the two S/I ratios for any rating (see Appendix A, Table A-1). Analysis of all individual ASVAB subtest scores did reveal a few significant differences, although they could be due simply to statistical chance (Table A-2). These differences were not consistent for either ratio, however, and it is considered that they did not affect the outcome of the research.

Instructors

Instructors for this study were four volunteers from the BE/E instructor pool. To control for instructor bias, the instructors were assigned to an LC using one S/I ratio for the first half of a session and to an LC using the other ratio for the second half. This process also counterbalanced the order of S/I ratio experienced by the instructors.

Analysis

Data analysis focused on comparing student achievement and instructor LC behavior obtained for the two S/I ratios. The majority of the student achievement data were obtained from the CMI system; and the remaining data (i.e., ASVAB scores, module completion times, first-try module test scores, and two phase test scores covering the direct current (DC) and alternating current (AC) course topics), from BE/E forms. Student data were analyzed in terms of attrition, training contract hours, first-try scores on module and phase tests, number of remediations per instructional module, and number of unsatisfactory scores received on practical tests.

Instructor-related data were gathered by observing each of the four instructors for four complete 6-hour shifts under each S/I ratio. The observation periods were systematically spaced across the data collection interval and across days of the week to control for any differential effects caused by day of observation. During each period, the research personnel recorded the frequency and duration of seven types of instructor behaviors:

1. Testing--Written. Administrative duties connected with written tests, such as processing test materials, conducting remediation tests, and grading tests when the computer system was malfunctioning.

2. Administration--Students. Administrative duties that involve students, such as signing a student in or out of the LC or changing a student's duty assignment.

3. Administration--Nonstudent. Administrative duties that do not involve students, such as filing papers, filling out forms, and discussing school-related topics with fellow staff members.

4. Responding to Questions. Student/instructor interactions in which technical questions about the course are answered. Includes instructional or tutorial services provided by the instructors.

5. Testing--Practical. Duties connected with the two practical tests performed in the LC (e.g., scoring and remediation).

6. Nonschool Activity. This behavior consisted of holding non-school-related conversations with other instructors.

7. Other. Such non-school-related behaviors as waiting for a student interaction, being on a break away from the LC, etc.

While monitoring instructor behavior, the observers were about 4 feet in back of the instructor, close enough so the conversations between students and instructors could be overheard. The observers had no direct contact with the students and only minimal necessary contact with the instructors. If a S/I conversation were private, the observer moved away or the student and instructor left the LC area. These personal conversations occurred very rarely. Analysis of instructor data also consisted of comparisons across the two S/I ratios.

RESULTS

Student Achievement

Table 2, which provides student attrition data, shows that the drop rates for the two groups are similar.

Data regarding training time were first analyzed for the entire course. Mean total training contact hours, including phase testing times, were computed for graduating students in each rating in the four module completion patterns. As shown in Table 3, which presents the results of the statistical t-tests, the only statistically significant comparisons occurred in pattern 2: The FTM ratings and the combined ratings that had completed the regular pattern required a significantly longer training time under the 30:1 condition than the 18:1 condition. The 30:1 condition resulted in longer training time for all other ratings (except for GMT and GMG), but the differences were not significant. For data on specific module performance, see Appendix B.

Table 2

Student Attrition Data

	S/I Ratio			
	18:1		30:1	
Item	N	Percent	N	Percent
Graduated	62	79.5	133	83.7
Dropped, academic reasons	12	15.4	21	13.2
Dropped, disciplinary reasons	4	5.1	5	3.1
Total sample	78	100.0	159	100.0

Table 3

Mean Total BE/E Training Contact Hours for Graduates

Module Comp. Pattern	Rating	S/I Ratio 18:1 Mean[a] Hours	18:1 N[b]	30:1 Mean[a] Hours	30:1 N	t
1	STG	98.48	5	110.03	12	--
	STS	86.98	4	111.93	15	--
Subtotal		94.14	9	111.09	27	--
2[c]	DS	175.50	2	256.73	6	--
	ETN:					
	Regular	204.31	8	224.79	9	--
	Splice	92.93	7	102.06	5	--
	ETR:					
	Regular	--	0	204.60	5	--
	Splice	76.00	2	99.58	6	--
	IC:					
	Regular	180.95	4	242.76	11	--
	Splice	--	0	157.50	2	--
	FTM	184.35	4	250.75	11	3.00*
	FTG	233.05	2	263.48	6	--
Subtotal		--	29	--	61	--
(Regular)		(195.64)	(20)	(242.49)	(48)	4.11**
(Splice)		(87.21)	(9)	(104.41)	(13)	--
3	EM	150.26	15	172.52	28	--
4	GMT	134.60	1	131.67	3	--
	GMG	128.70	5	118.87	7	--
Subtotal		129.68	6	120.97	10	--

[a]Includes times for module completion and phase tests.

[b]Subjects for whom complete data were not available were not included.

[c]In the regular pattern for ETNs, ETRs, and ICs, all 25 modules are taken at BE/E, San Diego; in the splice pattern, only modules 15-25 are taken at San Diego.

*$p < .01$.
**$p < .001$.

To provide a different perspective on the effects of S/I ratios on instructional time, phase test times were excluded from the analysis, and the mean instructional hours per module were computed and averaged for modules 1 through 14 and 15 through 25. As shown in Table 4, for modules 1 through 14, the combined ratings in pattern 2 and EMs in pattern 3 required significantly longer instruction time per module under the 30:1 condition than they did under the 18:1 condition. For all other ratings, except GMT and GMG, the 30:1 ratio resulted in longer instruction time per module, although the difference was not statistically significant.

For modules 15 through 25, the mean instruction hours per module again tended to be higher in the 30:1 condition than in the 18:1 condition. However, differences were significant only for the combined ratings in regular pattern 2 and for FTMs. In general, the training time data indicate that the 30:1 S/I ratio tends to result in longer training time.

To provide additional information, first-try module test scores were analyzed to determine whether different S/I ratios affected student performance. Mean first-try module test scores were computed for modules 1 through 14 and modules 15 through 25 for each rating. As shown in Table 5, there were no significant differences between mean test scores for either module group.

Other achievement measures were the first-try AC and DC phase test scores. These data were analyzed and are presented in Table 6, along with results from the statistical analyses. As shown, for the DC phase test, t-tests were significant for the combined ratings and the STSs in pattern 1, and for the EMs in pattern 3. No consistent superiority for either ratio is seen for any ratings. For the AC phase test, t-tests were significant for the DS and FTG ratings in module 2, but, again, no consistency is seen for these data. The significant differences for the phase test score data were not correlated with S/I ratio.

Since the variation in S/I ratio was expected to alter the availability of the instructor, and possibly affect the module study behavior of students, the number of remediations required by each rating to complete a module were averaged for the two clusters of modules--1 through 14 and 15 through 25. As shown in Table 7, in the first cluster, significant differences appeared for the combined ratings in patterns 1 and 4 and for the individual EM and GMG ratings. No meaningful trend is apparent, however, from these data, nor is there a good explanation for differences found. For BE&E Coursefile 69, slightly more than one remediation per module was necessary for completion.

The final student achievement measure was the number of unsatisfactory performance test (PT) attempts for each student. As shown in Table 8, which summarizes these data, the only significant difference between ratios was for students in the ETN rating in regular pattern 2.

Instructor Behavior

Table 9, which provides the mean proportion of time per hour instructors spent engaged in each behavior category, shows that those in the 30:1 condition spent more time in behaviors concerned with administration than did those in the 18:1 condition. This finding would be expected because there were more students in the 30:1 condition.

The 30:1 ratio also reduced the time the instructor spent on "other" activities. As shown, instructors in the 18:1 condition spent 24 percent of their time on other activities,

Table 4

Mean Instructional Hours Per Module Required by Graduates

Module Comp. Pattern	Rating	S/I Ratio 18:1 Mean Hours	18:1 N[a]	30:1 Mean Hours	30:1 N	t
		Modules 1 through 14				
1	STG	4.50	5	5.21	12	--
	STS	4.00	4	5.37	15	--
Subtotal		4.58	9	5.30	27	
2[b]	DS	4.71	2	7.29	6	--
	ETN (Reg.)	5.41	8	5.52	9	--
	ETR (Reg.)	--	0	6.62	5	--
	IC (Reg.)	4.78	4	7.07	11	--
	FTM	5.28	4	7.21	11	--
	FTG	6.60	2	7.56	6	--
Subtotal		5.30	20	6.88	48	3.77**
3	EM	4.51	15	6.03	28	2.21*
4	GMT	8.83	1	8.69	3	--
	GMG	8.38	5	7.78	7	--
Subtotal		8.46	6	7.91	10	
		Modules 15 through 25[c]				
2[b]	DS	6.12	2	8.02	6	--
	ETN:					
	Regular	6.38	8	8.04	9	--
	Splice	8.89	7	8.61	5	--
	ETR:					
	Regular	--	0	5.98	5	--
	Splice	5.49	2	7.12	6	--
	IC:					
	Regular	6.53	4	7.62	11	--
	Splice	--	0	8.93	2	--
	FTM	5.34	4	7.18	11	2.20*
	FTG	6.08	2	7.65	6	--
Subtotal		--	29	--	61	
(Regular)		(6.14)	(20)	(7.52)	(48)	2.58*
(Splice)		(7.98)	(9)	(7.97)	(13)	--
3	EM	10.31	15	11.69	28	--

[a]Subjects for whom complete data were not available were not included.

[b]In the regular pattern for ETNs, ETRs, and ICs, all 25 modules are taken at BE/E, San Diego; in the splice pattern, only modules 15-25 are taken at San Diego.

[c]Personnel in patterns 1 and 4 do not complete modules 15 through 25.

*$p < .05$.

**$p < .001$.

Table 5

Mean First-Try Module Test Scores Obtained by Graduates

Module Completion Pattern	Rating	S/I Ratio 18:1 Mean Score %	18:1 N[a]	30:1 Mean Score %	30:1 N
		Modules 1 through 14			
1	STG	85.58	5	89.96	12
	STS	87.56	4	89.72	15
Subtotal		85.85	9	89.78	27
2[b]	DS	86.56	2	87.23	6
	ETN (Reg.)	88.01	8	89.54	9
	ETR (Reg.)	--	0	84.52	5
	IC (Reg.)	89.60	4	85.16	11
	FTM	86.59	4	85.46	11
	FTG	80.03	2	85.16	6
Subtotal		87.10	20	86.18	48
3	EM	83.94	15	87.38	28
4	GMT	83.42	1	77.28	3
	GMG	81.58	5	84.55	7
Subtotal		81.88	6	82.46	10
		Modules 15 through 25[c]			
2[b]	DS	88.60	2	83.87	6
	ETN:				
	Regular	83.47	8	85.41	9
	Splice	86.45	7	83.96	5
	ETR:				
	Regular	--	0	89.85	5
	Splice	83.39	2	69.66	6
	IC:				
	Regular	87.68	4	73.85	11
	Splice	--	0	79.96	2
	FTM	84.31	4	81.46	11
	FTG	75.12	2	81.20	6
Subtotal		--	29	--	61
(Regular)		(84.16)	(20)	(82.12)	(48)
(Splice)		(87.02)	(9)	(76.75)	(13)
3 EM	81.29	15	85.43	28	

[a]Subjects for whom complete data were not available were not included.

[b]In the regular pattern for ETNs, ETRs, and ICs, all 25 modules are taken at BE/E, San Diego; in the splice pattern, only modules 15-25 are taken at San Diego.

[c]Personnel in patterns 1 and 4 do not complete modules 15 through 25.

Table 6

Mean First-Try Scores for DC and AC Phase Tests Obtained by Graduates

Module Completion Pattern	Rating	S/I Ratio 18:1 Mean Score (%)	18:1 N[a]	30:1 Mean Score (%)	30:1 N	t
		DC Phase				
1	STG	87.10	5	95.60	12	--
	STS	90.60	4	95.70	15	2.77*
Subtotal		89.33	9	96.64	27	3.01*
2[b]	DS	96.70	2	91.50	6	--
	ETN (Reg.)	95.29	8	94.32	9	--
	ETR (Reg.)	--	0	93.80	5	--
	IC (Reg.)	95.58	4	90.82	12	--
	FTM	95.58	4	94.87	11	--
	FTG	84.45	2	91.48	6	--
Subtotal		94.62	20	92.56	49	--
3	EM	94.77	14	90.53	26	3.12**
4	GMT	91.10	1	87.40	3	--
	GMG	90.66	5	91.44	7	--
Subtotal		90.73	6	89.70	10	--
		AC Phase				
1	STG	83.60	5	85.30	12	--
	STS	88.00	4	88.40	15	--
Subtotal		87.00	9	87.04	27	--
2[b]	DS	96.00	2	82.67	6	2.91*
	ETN (Reg.)	83.50	8	84.89	9	--
	ETR (Reg.)	--	0	91.20	5	--
	IC (Reg.)	72.50	4	78.90	11	--
	FTM	82.00	4	84.36	11	--
	FTG	73.00	2	84.29	7	2.83*
Subtotal		81.20	20	83.62	49	--
3	EM	85.70	14	87.30	28	--
4	GMT	78.80	1	86.87	3	--
	GMG	81.78	4	86.13	7	--
Subtotal		81.18	5	84.84	10	--

[a]Subjects for whom complete data were not available were not included.

[b]In the regular pattern for ETNs, ETRs, and ICs, all 25 modules are taken at BE/E, San Diego; in the splice pattern, only modules 15-25 are taken at San Diego.

Table 7

Mean Number of Remediations Per Module Required by Graduates

Module Completion Pattern	Rating	S/I Ratio 18:1 Mean Number	18:1 N[a]	30:1 Mean Number	30:1 N	t
		Modules 1 through 14				
1	STG	1.16	5	0.90	12	--
	STS	1.35	4	0.77	15	--
Subtotal		1.36	9	0.83	27	-2.23*
2[b]	DS	1.13	2	.96	6	--
	ETN (Reg.)	1.00	8	1.05	9	--
	ETR (Reg.)	--	0	1.36	5	--
	IC (Reg.)	0.76	4	1.41	11	--
	FTM	0.96	4	1.45	11	--
	FTG	2.15	2	1.50	6	--
Subtotal		1.07	20	1.32	48	
3	EM	.57	15	1.16	28	3.14*
4	GMT	2.73	1	2.08	3	--
	GMG	2.20	5	1.31	7	-2.32*
Subtotal		2.29	6	1.54	10	-2.29*
		Modules 15 through 25[c]				
2[b]	DS	1.31	2	1.64	6	--
	ETN:					
	Regular	1.60	8	1.64	9	--
	Splice	1.37	7	1.40	5	--
	ETR:					
	Regular	--	0	1.28	5	--
	Splice	1.50	2	1.14	6	--
	IC:					
	Regular	1.47	4	1.66	11	--
	Splice	--	0	2.07	2	--
	FTM	1.72	4	1.81	11	--
	FTG	2.13	2	1.96	6	--
Subtotal		--	29	--	61	--
(Regular)		(1.62)	(20)	(1.67)	(48)	--
(Splice)		(1.41)	(9)	(1.38)	(13)	--
3	EM	1.57	15	1.90	28	--

[a]Subjects for whom complete data were not available were not included.

[b]In the regular pattern for ETNs, ETRs, and ICs, all 25 modules are taken at BE/E, San Diego; in the splice pattern, only modules 15-25 are taken at San Diego.

[c]Personnel in patterns 1 and 4 do not complete modules 15 through 25.

*$p < .05$.

Table 8

Mean Number of Unsatisfactory Performance Test Attempts Made by Graduates

Module Completion Pattern	Rating	S/I Ratio 18:1 Mean Number	18:1 N[a]	30:1 Mean Number	30:1 N
1	STS	0.50	4	1.00	8
	STG	1.00	3	0.75	8
Subtotal		0.62	7	0.88	16
2[b]	DS	2.50	2	3.30	6
	ETN				
	Regular	6.88	8	2.12*	8
	Splice	2.83	6	3.60	5
	ETR				
	Regular	--	0	3.75	4
	Splice	3.50	2	4.20	5
	IC				
	Regular	1.50	4	3.33	9
	Splice	--	0	6.50	2
	FTM	3.00	4	4.20	9
	FTG	1.50	2	4.20	6
Subtotal		--	28	--	54
(Regular)		(4.05)	(20)	(3.58)	(42)
(Splice)		(2.22)	(8)	(4.33)	(12)
3	EM	4.36	14	3.38	21
4	GMT	1.00	1	1.50	2
	GMG	1.80	5	1.17	6
Subtotal		1.67	6	1.22	8

[a]Subjects for whom complete data were not available were not included.

[b]In the regular pattern for ETNs, ETRs, and ICs, all 25 modules are taken at BE/E, San Diego; in the splice pattern, only modules 15-25 are taken at San Diego.

*$p < .01$.

Table 9

Mean Percent of Instruction Hour for and Average Duration of Each Type of Instructor Behavior

Instructor Behavior Type	S/I Ratio			
	18:1		30:1	
	% of Inst. Hr.	Average Duration (Min.)	% of Inst. Hr.	Average Duration (Min.)
Testing--Written	22	1.2	29	1.1
Admin.--Student	17	1.0	23	1.0
Admin.--Nonstudent	18	1.6	15	1.4
Responding to Questions	14	2.2	12	1.7*
Testing--Practical	4	1.1	5	1.0
Nonschool Activity	1	0.8	1	0.5
Other	24	2.6	15	2.4
Subtotal	100		100	

*$p < .05$.

compared to 15 percent for those in the 30:1 condition. Since a major characteristic of individualized learning is maximum accessibility of the instructor, even a slight reduction in available instructor time is not desirable.

To see how the increased number of students affected each individual instructor activity, the average duration of instructor activity was computed for each type. As shown in Table 9, the 30:1 ratio resulted in significantly less time spent per question answering technical questions than did the 18:1 ratio. This is understandable because, with more students, the instructor spends more time on administrative activities and has less time for tutorial-type behaviors.

DISCUSSION AND CONCLUSIONS

Although students generally performed equally well in both 30:1 and 18:1 ratios in terms of module and phase-test scores, the mean number of training contact hours was generally greater for students in the 30:1 condition. This was true even when instructional hours only were considered for module clusters 1 through 14 or 15 through 25. For example, the students who took all 25 modules in the 30:1 S/I ratio took approximately 45 hours longer to complete the course than did those in the 18:1 condition. The cost of these extra hours in training must be carefully weighed against the savings that would be obtained by reducing the number of instructors.

Analysis of the number of required remediation attempts per module showed some differences due to S/I ratios, although these differences did not consistently favor one

ratio. Similarly, analysis of the number of unsatisfactory PT attempts revealed a few significant differences for the two ratio conditions, but, again, the differences were not consistent. This finding is not surprising, since PTs were generally conducted in the PT laboratory and were not under the direct control of the LC instructor.

In general, the student data showed that a larger S/I ratio did not adversely affect achievement in the BE&E course, but it did increase training time. Evidently, when the S/I ratio was increased, the available instructor time per student was reduced. This conclusion is supported by the instructor behavior data.

Analysis of instructor behavior during an instructional hour revealed that, with the 30:1 S/I ratio, instructors spent less time answering technical questions and in "other" activities, and more time in administration activities. It should be emphasized that, in the 18:1 S/I ratio, the instructor was fully occupied; in the 30:1 S/I ratio, the instructor was extremely busy. Although 15 to 25 percent of the instructional hour was spent in noninstructional and nonadministrative activities, this does not mean the instructor was "free" or on breaks that much of the time. Rather, the percent of time reflects the average total time per hour, made up of many short intervals, when the instructor is not obviously occupied. It is the only time when the instructor can get organized before the next student interaction.

Analysis of the amount of time spent during each interaction further clarifies the difference found in instructor activities for the ratios. This analysis reveals that instructors spent less time per question answering each student's technical questions in the 30:1 S/I ratio condition than in the 18:1 condition. This probably occurred because there were more students asking questions and requiring administrative interactions, thereby requiring the instructor to reduce the time spent answering each question. To the extent that a CMI course requires S/I administrative interactions, there is naturally less time for technical interactions that directly benefit student learning. Accordingly, future CMI courses should maximize use of computerized administrative interactions and minimize use of instructor-generated administrative interactions. This contention is supported by the fact that the BE&E schools are now using a new coursefile (Coursefile 71) in which the computer performs administrative functions formerly performed by instructors. Additionally, instructors have been freed of some troubleshooting responsibilities and many clerical duties, and can spend more time with students.

Although this research found that an increase in the S/I ratio resulted in increased training time, this effect might be mitigated by other factors. For example, at the BE&E school, San Diego, the coursefile has been changed to relieve the instructor of administrative duties and give him more time for student assistance. There may be other mitigating approaches, and since training time is critical and the pressure to reduce the number of instructors continues, more research is necessary to ensure the most efficient and effective training procedures. This future research would involve larger sample sizes and a wider range of ratios, since different schools will no doubt make different demands on instructors and students. Adequate sample sizes are necessary to relate the S/I ratio variable to other relevant variables, such as LC configuration, course types, and CMI testing strategies. Procedures that would permit increasing the S/I ratio without affecting student achievement or CMI training time would produce a significant reduction in training costs.

RECOMMENDATIONS

1. When revising or developing CMI courses, technical-training program coordinators and CMI course designers should alter CMI course-management strategies so that administrative functions currently performed by instructors or students are performed by the computer.

2. Technical training schools should obtain performance data for both students and instructors during any future efforts to increase S/I ratios on an operational basis. These performance data must be related with other variables to determine the overall effects of S/I ratio changes. Future analyses of S/I ratios should include such variables as LC operating procedures, course content, and knowledge and performance testing strategies.

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APPENDIX A

ARMED SERVICES VOCATIONAL APTITUDE BATTERY QUALIFYING SCORES FOR BE&E GRADUATES AND SIGNIFICANT COMPARISONS FOR EACH RATING

Table A-1

Comparison of Mean ASVAB Qualifying Scores for BE&E Graduates for each Rating and S/I Ratio

		S/I Ratio			
		18:1		30:1	
Module Pattern	Rating	Mean Score	N[a]	Mean Score	N
1	STG	259.5	2	249.7	3
	STS	241.0	1	255.2	6
2[b]	DS	238.0	2	251.4	5
	ETN				
	Regular	242.1	7	240.2	8
	Splice	255.0	7	252.0	4
	ETR				
	Regular	--	0	239.6	5
	Splice	232.0	2	241.8	5
	IC[c]	175.7	3	170.6	10
	FTM	252.2	4	241.4	8
	FTG	254.5	2	242.6	5
3	EM[c]	184.3	15	180.1	25
4	GMT[c]	157.0	1	160.7	3
	GMG[c]	171.4	5	175.1	7

[a]Subjects for whom complete data were not available were not included.

[b]In the regular pattern for ETNs, ETRs, and ICs, all 25 modules are taken at BE/E, San Diego; in the splice pattern, only modules 15-25 are taken at San Diego.

[c]The ASVAB qualification equation for this rating is WK + MC + SI; the equation for the other ratings listed is MK + EI + GS + AR.

Table A-2

Ratings In Which Mean ASVAB Subtest
Score Comparisons were Statistically Significant

Module Completion Pattern	Rating	Sub-test[a]	S/I Ratio 18:1 Mean	18:1 N[b]	30:1 Mean	30:1 N	t
1	STG	SI	51.00	3	52.75	4	--
	STS	SI	52.00	1	62.89	9	5.31***
Subtotal			51.00	4	60.00	9	2.26*
2[c]	DS	AD	65.50	2	50.83	6	--
		MC	53.50	2	62.67	6	--
	ETN	AD	57.20	14	53.60	14	--
		MC	62.40	14	58.10	14	--
	ETR	AD	54.50	2	48.50	1	--
		MC	56.50	2	58.00	11	--
	IC	AD	52.80	4	49.40	13	--
		MC	63.50	4	54.00	14	--
	EW	AD	56.00	1	43.50	2	--
		MC	69.00	1	50.00	2	--
	FTM	AD	61.30	4	49.70	10	-3.62**
		MC	62.00	4	59.60	10	--
	FTG	AD	57.50	2	51.70	6	--
		MC	63.00	2	60.50	6	--
Subtotal		AD	57.53	29	50.43	52	-4.83***
		MC	62.00	29	58.00	63	-2.52*
3	EM	AR	64.00	15	59.00	27	-2.36*
		MR	65.00	15	62.00	27	-2.02*

[a] SI = Shop Information, AD = Attention to Detail, MC = Mechanical Comprehension, AR = Arithmetic Reasoning, and MR = Mathematical Reasoning.

[b] Subjects for whom complete data were not available were not included.

[c] In the regular pattern for ETNs, ETRs, and ICs, all 25 modules are taken at BE/E, San Diego; in the splice pattern, only modules 15-25 are taken at San Diego.

*p < .05.
**p < .01.
***p < .001.

APPENDIX B

MEAN MODULE COMPLETION TIMES FOR INDIVIDUAL BE&E MODULES

Table B-1

Mean Module Completion Times for BE/E Graduates

Rating	S/I Ratio 18:1 Mean Hours	18:1 N	30:1 Mean Hours	30:1 N	p <
Module 1					
STG	3.04	5	3.36	11	--
SGS	2.03	3	3.57	15	--
DS	2.00	2	5.45	6	.020
ETN	1.80	5	2.73	8	--
ETR	.00	0	4.08	4	--
IC	4.47	3	6.36	11	--
FTM	1.95	4	5.35	11	.005
FTG	5.25	2	5.31	6	--
EM	3.26	13	3.85	24	--
GMT	11.10	1	6.17	3	--
GMG	4.94	5	4.26	6	--
Module 2					
STG	3.24	5	5.19	12	--
SGS	3.80	3	4.25	15	--
DS	5.70	2	5.02	6	--
ETN	4.48	5	6.45	8	--
ETR	0.00	0	8.34	5	--
IC	5.34	3	6.61	11	--
FTM	5.05	4	7.14	11	--
FTG	7.35	2	6.04	5	--
EM	3.52	13	5.51	24	--
GMT	15.00	1	9.83	3	--
GMG	9.62	5	10.55	6	--
Module 3					
STG	3.58	5	4.68	12	--
SGS	3.68	4	5.08	15	--
DS	7.25	2	4.22	6	--
ETN	5.57	7	5.18	8	--
ETR	0.00	0	7.38	5	--
IC	6.03	3	5.86	12	--
FTM	4.70	4	5.78	11	--
FTG	3.90	2	5.44	5	--
EM	6.20	14	4.99	22	--
GMT	8.90	1	7.20	3	--
GMG	10.04	5	7.23	6	--

Note: Ns represent only students with complete data.

Table B-1 (Continued)

Rating	S/I Ratio 18:1 Mean Hours	18:1 N	30:1 Mean Hours	30:1 N	p <
Module 4					
STG	4.26	5	5.42	12	--
SGS	3.73	4	5.12	15	--
DS	4.50	2	7.10	6	--
ETN	6.66	7	6.19	8	--
ETR	0.00	0	6.90	5	--
IC	4.20	4	7.53	12	--
FTM	5.83	4	7.48	11	--
FTG	7.05	2	7.93	6	--
EM	5.75	14	6.99	27	--
GMT	6.30	1	12.10	3	--
GMG	11.80	5	9.32	6	--
Module 5					
STG	4.18	5	5.34	12	--
SGS	2.70	4	5.55	15	--
DS	2.30	2	8.55	6	--
ETN	5.73	7	3.47	9	--
ETR	0.00	0	5.80	5	--
IC	2.98	4	8.29	12	--
FTM	7.40	4	6.07	11	--
FTG	3.10	2	6.45	6	--
EM	5.33	12	4.79	26	--
GMT	15.00	1	8.37	3	--
GMG	7.82	5	9.33	6	--
Module 6					
STG	6.00	5	6.25	12	--
SGS	3.73	4	6.13	15	--
DS	6.60	2	8.05	6	--
ETN	6.25	8	6.68	9	--
ETR	0.00	0	8.16	5	--
IC	7.25	4	9.04	12	--
FTM	7.18	4	9.56	11	--
FTG	9.50	2	11.62	6	--
EM	5.16	14	9.40	27	--
GMT	12.50	1	11.10	3	--
GMG	15.40	5	11.07	6	--
GMM	0.00	0	14.60	1	--

Note: Ns represent only students with complete data.

Table B-1 (Continued)

Rating	S/I Ratio 18:1 Mean Hours	18:1 N	30:1 Mean Hours	30:1 N	p <
Module 7					
STG	13.32	5	13.71	12	--
SGS	11.33	4	12.96	14	--
DS	11.80	2	21.72	6	--
ETN	13.70	8	15.23	9	--
ETR	0.00	0	18.92	5	--
IC	12.90	4	21.56	12	--
FTM	17.10	4	17.14	11	--
FTG	14.05	2	19.05	6	--
EM	13.44	14	17.36	27	--
GMT	20.10	1	20.80	3	--
GMG	24.84	5	20.90	7	--
Module 8					
STG	5.04	5	4.42	12	--
SGS	4.38	4	4.49	15	--
DS	3.80	2	4.83	6	--
ETN	2.94	8	4.62	9	--
ETR	0.00	0	4.36	5	--
IC	4.35	4	4.95	12	--
FTM	4.73	4	6.35	11	--
FTG	6.75	2	4.60	7	--
EM	4.58	14	5.27	27	--
GMT	8.30	1	7.27	3	--
GMG	4.42	5	5.26	7	--
Module 9					
STG	7.58	5	6.33	12	--
SGS	5.48	4	6.82	15	--
DS	5.00	2	8.50	6	--
ETN	7.10	8	7.36	9	--
ETR	0.00	0	8.30	5	--
IC	5.88	4	8.56	12	--
FTM	5.50	4	9.99	11	.03
FTG	6.35	2	9.73	7	--
EM	6.23	14	8.32	26	--
GMT	8.90	1	10.97	3	--
GMG	8.26	5	8.89	7	--

Note: Ns represent only students with complete data.

Table B-1 (Continued)

Rating	S/I Ratio 18:1 Mean Hours	18:1 N	30:1 Mean Hours	30:1 N	p <
Module 10					
STG	4.68	5	5.18	12	--
SGS	3.98	4	6.10	15	--
DS	3.70	2	6.40	6	--
ETN	6.13	7	5.64	9	--
ETR	0.00	0	6.38	5	--
IC	4.73	4	6.29	12	--
FTM	3.25	4	6.84	11	.02
FTG	7.65	2	6.90	7	--
EM	5.04	14	5.45	28	--
GMT	9.60	1	6.57	3	--
GMG	6.80	5	5.74	7	--
Module 11					
STG	2.60	5	3.57	12	--
SGS	3.15	4	3.82	15	--
DS	2.65	2	3.52	6	--
ETN	3.64	8	3.29	9	--
ETR	0.00	0	4.90	5	--
IC	5.83	4	4.78	12	--
FTM	2.58	4	5.46	11	.02
FTG	5.20	2	5.10	7	--
EM	2.89	14	4.14	28	--
GMT	7.00	1	3.60	3	--
GMG	3.90	5	2.81	7	--
Module 12					
STG	3.80	5	5.29	12	--
SGS	2.75	4	4.75	15	--
DS	3.30	2	9.50	6	.03
ETN	5.61	8	5.09	9	--
ETR	0.00	0	6.92	5	--
IC	3.60	4	8.56	12	--
FTM	6.10	4	6.96	10	--
FTG	7.05	2	7.73	7	--
Module 13					
STG	6.98	5	6.19	12	--
SGS	6.65	4	7.22	15	--
DS	8.30	2	9.72	6	--
ETN	7.54	7	7.72	9	--
ETR	0.00	0	7.58	5	--
IC	6.10	4	13.32	12	--
FTM	8.13	4	7.90	11	--
FTG	8.00	2	8.21	7	--

Note: Ns represent only students with complete data.

Table B-1 (Continued)

Rating	S/I Ratio 18:1 Mean Hours	18:1 N	30:1 Mean Hours	30:1 N	p <
Module 14					
STG	4.86	5	5.93	12	--
SGS	4.45	4	6.77	15	--
DS	3.70	2	10.33	6	--
ETN	6.36	8	5.63	9	--
ETR	0.00	0	6.16	5	--
IC	5.33	4	6.81	12	--
FTM	6.68	4	8.26	11	--
FTG	11.75	2	8.91	7	--
Module 15					
DS	3.55	2	2.93	6	--
ETN	3.12	9	4.02	10	--
ETR	0.00	0	1.90	5	--
IC	2.23	4	4.08	13	--
FTM	1.78	4	3.29	11	.01
FTG	3.00	2	4.84	7	--
EM	4.39	14	2.98	28	--
Module 16					
DS	0.90	2	5.48	6	--
ETN	1.99	9	4.60	10	--
ETR	0.00	0	4.88	5	--
IC	5.58	4	7.56	13	--
FTM	2.33	4	6.86	11	.02
FTG	8.55	2	6.09	7	--
EM	5.24	14	6.29	28	--
Module 17					
DS	4.05	2	5.45	6	--
ETM	3.56	10	10.44	11	.02
ETR	5.85	6	5.91	6	--
IC	7.80	4	11.07	13	--
FTM	1.90	4	11.30	11	.002
FTG	9.70	2	10.30	7	--
EM	7.29	14	8.80	28	--
Module 18					
DS	2.95	2	4.45	6	--
ETN	5.05	11	5.47	12	--
ETR	0.00	0	5.80	7	--
IC	2.55	4	7.79	13	.024
FTM	3.88	4	6.59	11	--
FTG	7.60	2	6.80	7	--
EM	4.90	14	6.09	28	--

Note: Ns represent only students with complete data.

Table B-1 (Continued)

Rating	S/I Ratio 18:1 Mean Hours	18:1 N	30:1 Mean Hours	30:1 N	p <
Module 19					
DS	.75	2	1.82	6	--
ETN	1.49	11	4.48	12	.025
ETR	0.00	0	3.50	7	--
IC	1.38	4	3.33	13	--
FTM	1.15	4	2.38	11	--
FTG	4.30	2	3.17	7	--
EM	2.87	14	3.71	28	--
Module 20					
DS	12.80	2	13.87	6	--
ETN	10.31	13	12.13	13	--
ETR	0.00	0	12.94	9	--
IC	11.80	4	12.58	13	--
FTM	9.03	4	12.39	11	--
FTG	12.05	2	12.73	7	--
EM	12.03	14	13.01	28	--
Module 21					
DS	9.60	2	16.95	6	--
ETN	12.88	14	13.45	13	--
ETR	0.00	0	14.93	9	--
IC	12.23	4	14.36	13	--
FTM	10.03	4	12.53	11	--
FTG	11.85	2	15.46	7	--
EM	14.08	14	15.06	28	--
Module 22					
DS	6.60	2	9.95	6	--
ETN	7.41	15	10.00	13	--
ETR	0.00	0	8.22	9	--
IC	8.48	4	8.84	13	--
FTM	7.88	4	7.60	11	--
FTG	6.95	2	11.27	7	--
Module 23					
DS	7.45	2	9.82	6	--
ETN	8.39	15	13.20	14	--
ETR	8.75	2	8.67	10	--
IC	6.75	4	8.55	13	--
FTM	6.30	4	10.08	11	--
FTG	5.45	2	8.03	7	--
EM	10.04	14	10.65	28	--

Note: Ns represent only students with complete data.

Table B-1 (Continued)

Rating	S/I Ratio 18:1 Mean Hours	18:1 N	30:1 Mean Hours	30:1 N	p <
Module 24					
DS	5.45	2	5.40	6	--
ETN	4.81	15	6.60	14	--
ETR	2.20	2	4.60	10	--
IC	4.20	4	6.25	13	--
FTM	3.70	4	5.18	11	--
FTG	3.80	2	5.30	7	--
Module 25					
DS	5.00	2	6.35	6	--
ETN	17.87	15	7.50	14	--
ETR	2.70	1	6.73	10	--
IC	6.28	4	8.39	13	--
FTM	4.55	4	7.12	11	--
FTG	4.10	2	4.97	7	--
EM	8.05	14	8.05	28	--

Note: Ns represent only students with complete data.

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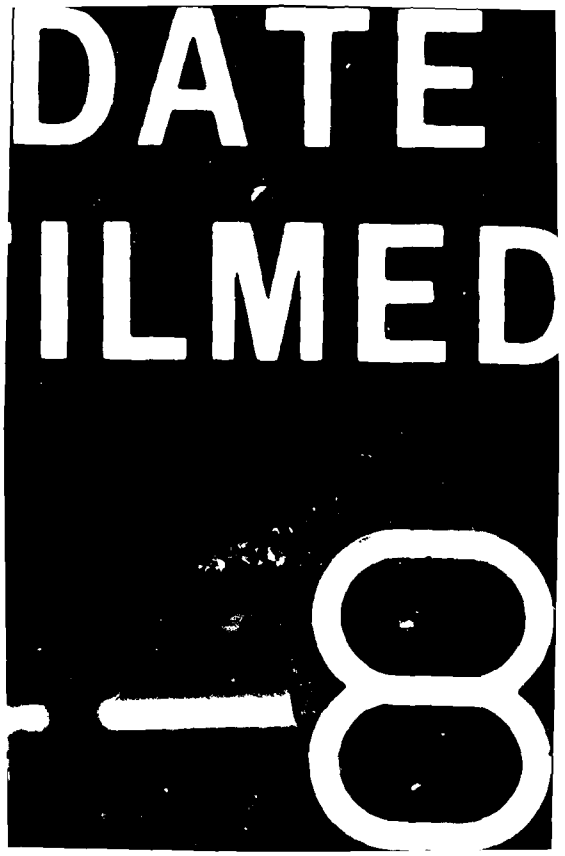
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